Development of an Efficient Detector System for Megavoltage Photons

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Detectors for megavoltage photons are used in radiation therapy to verify the treatment including accurate patient positioning. Commercially available systems, however, suffer from their low detection efficiency. This work investigated a novel, highly efficient approach of megavoltage photon detection and imaging including the development of small-scale prototype detectors and design considerations of a large-scale system. A sufficient amount of metal is placed along the direction of the photon beam so that the beam is almost completely attenuated. The metal forms an array with interspersed gas cavities. The high-energy charged particles, created by megavoltage photon interactions, deposit their energy in the gas through ionization events resulting in a recordable signal.

The first prototypes consisted of different single brass tubes filled with gas. Saturation curves as well as the detector signal as a function of the gas pressure were measured for air and xenon. Megavoltage computed tomography images of a contrast resolution phantom were acquired. A proposed large-scale detector array was investigated using Monte Carlo methods. One analysis relied on the determination of the primary signal and the crosstalk. As a first step towards a more comprehensive analysis, the presampling modulation transfer function (MTF_{pre}) was determined. Three different methods were worked out. In addition, the feasibility of the determination of the digital noise power spectrum (NPS_d) using the Monte Carlo technique was investigated.

The prototype detectors behaved in a predictable way based on the principles of ionimetry. A high density gas like xenon at a high pressure is required to ensure a sufficiently large detector signal. Monte Carlo simulations demonstrated the superiority of high density and high atomic number metals as the wall material since they result in a high primary signal with a minimum amount of crosstalk. The choice of an appropriate wall thickness depends on many factors such as the dimensions of the detector element, the photon spectrum used, etc. The methods to determine MTF_{pre} were found to be generally applicable to detectors with a severely inhomogeneous detection medium. The determination of NPS_d is severely hampered by time constraints. The thesis concludes with design considerations of a large-scale detector.